

MAINTENANCE HUMAN FACTORS FROM A EUROPEAN RESEARCH PERSPECTIVE: RESULTS FROM THE ADAMS PROJECT AND RELATED RESEARCH INITIATIVES

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Summary

The Aircraft Dispatch and Maintenance Safety (ADAMS) project was the first major European study in which the maintenance industry and researchers collaborated to investigate nature and extent of Human Factors aspects in aircraft maintenance. A strong commitment to safety was observed, but also a double standard that allows the official and the actual way of working to exist next to each other. About one-third of the technicians appear to deviate from the official maintenance procedures. Time pressure and inefficiency of the procedures are cited as the main reasons. Technicians and their managers perceive the technician's job differently resulting in a Job Perception Gap that creates time pressure and makes the maintenance operation less effective. Frequent use is being made of so-called blackbooks that contain private notes with useful detailed information. For routine tasks these notes are an important source of information used by the technician. There appears to be consensus in the industry that the importance of written procedures varies with the type of task. Safety risks result from the inability of the aviation community as a whole to have an open discussion on this topic. It is suggested to study other means of task support and to find legal and controlled alternatives for the blackbook. Human Factors training is a crucial means to raise awareness among technicians about the existence and risks of Human Factors problems. The effect of delivering only knowledge in such training will be of short duration. Skills and attitude should be developed to achieve real change. A cost-effective way to realise this is to integrate Human Factors with the technical training. The appearance of and reasons behind Human Factors problems differ between Line and Base Maintenance. It should be considered to approach the two differently, in training as well as in means of task support. Solutions to the existing Human Factors problems in maintenance should be sought further than in training only.

The need for Human Factors attention

Human Factors certainly is not an invention of the last ten years, though awareness of its existence and importance in aircraft maintenance was only raised after the well-known Aloha B-737 accident in 1988. As aircraft maintenance is planned and carried out by humans, it is only natural that errors will occur. This was the case in the early days of flight, it is still so today, and human error will not be excluded in the future. We will have to accept this and a logical conclusion is that we can only try to make the maintenance system as error tolerant as possible.

Deficiencies in maintenance are estimated to be involved in 12% of major accidents and 50% of engine-related flight delays (Hobbs, 2000). Accident statistics suggest an increase in maintenance related accidents. Boeing indicates maintenance as the primary cause in 6.0% of all accidents over the last ten years, where this figure was 3.4% over the last forty years (Rankin, 1999). Similarly, the number of maintenance errors

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reported to the UK CAA has increased significantly over the past couple of years (Hall, 1999). To some extent the quoted increase may be coloured by the increased awareness of Human Factors and human error. The same human error reported today might have occurred twenty years ago without having been recognised or without it having consequences other than blaming the individual that erred. Whether the situation actually is deteriorating or not, the figures currently known about the role of human error clearly indicate that we should study why these errors occur and then improve the maintenance system. To convince those who still believe that Human Factors is just another buzz-word we should perhaps put more emphasis on the related costs and not only on the safety aspect.

A couple of accidents in the beginning of the nineties triggered interest in maintenance Human Factors within Europe. Reason's model (Reason, 1990) has done much to explain the impact and danger of so-called 'latent failures' within the maintenance system. One of the lessons from Reason is that instead of cutting short an (incident) investigation concluding 'human error', root causes for this error should be traced back. The Reason model itself can very well function as a guide during such an investigation to make sure that all latent failures involved in the incident are disclosed. A growing number of organisations is routinely addressing Human Factors and latent failures in their investigations. However, there are still investigations that conclude their (public) report with a statement like '*both selflocking nuts had not been torqued [...] with the prescribed torque*' (German Federal Bureau of Aircraft Accidents Investigation, 1997). No explanations are given as to why the technician in this case did not apply the required torque value. Did he use the proper tooling, was his task interrupted, did he consult the maintenance manual? When the contributing factors remain unknown or poorly understood, all that is left is to anxiously wait for the next technician to make the same error.

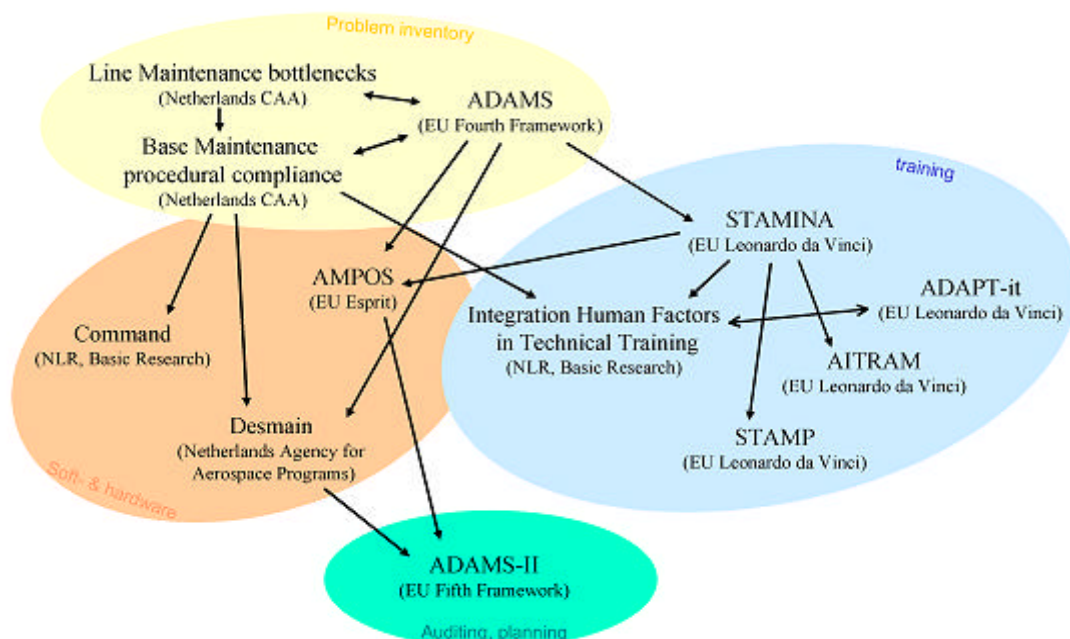


Figure 1 Relation between ADAMS and other research projects on Maintenance Human Factors (see Appendix A for description)

The ADAMS project

In 1995 the European Commission decided to fund under its Fourth Framework Research Programme a consortium of maintenance organisations and researchers to study nature and extent of Human Factors in aircraft maintenance. The resulting ADAMS (Aircraft Dispatch and Maintenance Safety) project can be considered the first major research effort within Europe studying Maintenance Human Factors. The project, co-ordinated by Trinity College Dublin (TCD), ran from 1996 until 1999, was organised into two phases. In the first phase the existing situation was investigated addressing issues like procedural compliance, organisational aspects and the role of modern technology. A comprehensive taxonomy was developed to identify all the potential contributory factors to an incident. In the second phase the project focused on some potential improvements. Based on the error taxonomy an error reporting form was developed and a curriculum

for Maintenance Human Factors training was specified. With the knowledge collected in the first research phase on existing Human Factors bottlenecks NLR realised the prototype of a new concept for maintenance documentation. The lessons learned in the project were documented in the guide on Human-Centred Management for Aircraft Maintenance (McDonald et. al., 1999) which is available from Trinity College Dublin.

The ADAMS project has resulted in a number of other research projects each addressing a specific problem area (see Figure 1). As a leitmotiv in NLR's work in the area of maintenance Human Factors each of the projects conducted aims to make aircraft maintenance less vulnerable to the shortcomings of written procedures. In the remainder of this paper a selection of results from the ADAMS project and objectives and approach of its successors are discussed.

Two studies were conducted as part of the ADAMS project to identify existing bottlenecks in aircraft maintenance. Bottlenecks were in this case defined as those aspects of the maintenance system that are limiting the overall efficiency and/or safety of the system. A series of structured interviews with operational personnel were conducted within three of the maintenance organisations participating in the consortium. The decision to choose such a bottom-up approach was made with the notion that a top-down approach that would take procedures and documentation as the starting-point would merely result in a method very similar to normal auditing practices. The second study was of a quantitative nature and focused on procedural compliance. By asking technicians to answer a questionnaire attached to their task card data was collected about the percentage of people consulting the manual and following the documented procedure.

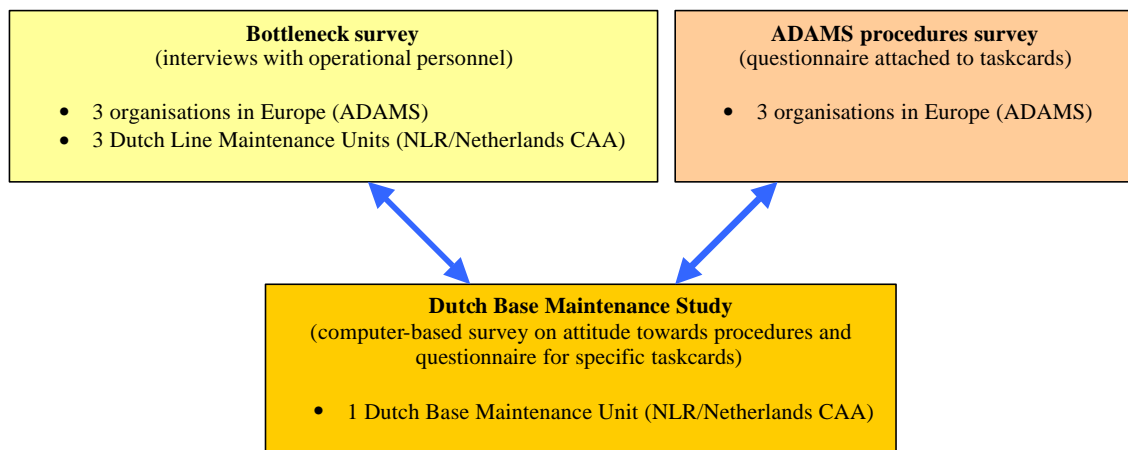


Figure 2 Relation between ADAMS surveys and additional work carried out for the Netherlands Civil Aviation Authorities

Additional work within the Netherlands

Sponsored by the Dutch civil aviation authorities NLR was able to collect data in three additional maintenance organisations within the Netherlands. In parallel with the ADAMS bottleneck survey interviews were conducted within the Line Maintenance units of these organisations. The main reason for this additional work was to investigate whether the Dutch situation differed in any way from that in other European countries. Such a difference could be the result of e.g. specific national legislation or differences in the education and training of maintenance personnel. The study within the Netherlands did confirm the bottlenecks identified by the ADAMS consortium to a large extent, but on a small number of items differences did exist. Given the small differences with the findings in ADAMS the second phase of the work in Base Maintenance concentrated on procedures and procedural compliance only. Again, the results obtained were, in general terms, comparable with those found in the ADAMS procedures survey conducted by Trinity College Dublin. Because the Base Maintenance study within the Netherlands started with the ADAMS results already available it provided an opportunity to zoom in on specific ADAMS observations (see also Figure 2).

In this paper we will not go into detail on the differences observed in the Dutch situation when compared to the findings of ADAMS. We will merely list the most important briefly:

Extremely long working hours (double shifts or longer) were observed in the ADAMS survey. In some cases there appeared to be a policy to let one specialised team carry out a complex and lengthy task from start to completion instead of handing over at some point to the next shift. Risks involved in task hand-over were quoted to play a role. Some technicians demonstrated a dangerously low awareness of the possible consequences of fatigue. Within the Netherlands a similar policy to avoid task hand-over was observed, but this was said not to lead to extremes in working hours (max. 12 hours).

Line maintenance technicians in the Netherlands normally hold a maximum of two type licenses. In specific circumstances, e.g. phasing out of a specific aircraft type, this number can be higher but with a maximum of four observed. Some of the organisations surveyed by ADAMS were said not to have a formal limit on the number of licenses a technician could hold. One of the technicians interviewed held eight full licenses. It is left to the reader to think about the chances for this technician to mix up details from different aircraft types, especially in the light of the bottlenecks described in the sections to come.

Main bottlenecks identified

A full report on the bottlenecks identified by the ADAMS surveys can be found in (Biemans et. al., 1998). In this section we will discuss a selection of the main findings.

Procedural compliance and maintenance documentation

Based on what is known from incident investigations it should not come as a surprise that people deviate from procedures. Yet, we didn't have an idea about the percentage of maintenance tasks this involved. In the ADAMS procedures survey 286 questionnaires were completed. Analysis of these revealed that in 34% of all cases the respondents said that they had completed the task using a method other than that which was in the Maintenance Manual. In another ten percent of the cases technicians indicated that they had followed the Manual but without consulting the manual before task execution. The Base Maintenance survey within the Netherlands was based on a smaller number of respondents and conducted with just one maintenance organisation, but resulted in a similar figure: 26% non-compliance and 9% not consulted (Hakkeling-Mesland, 2000).

When asked about the reason for not following the prescribed procedure technicians in the ADAMS procedural survey answered that there was an easier and quicker way than the official method (McDonald et. al., 1999). About one third (35%) indicated that they did not have the time needed to follow the method from the Maintenance Manual completely. There seems to exist consensus among the technicians interviewed in the bottleneck survey about the fact that the need for procedures varies with the type of task. For highly routine tasks it is considered not necessary to consult a manual and to follow the procedure documented in it, where the Manual is said to be necessary for conducting a test in order not to forget specific steps. A similar statement can be observed in relation to the experience of the technician: as a technician becomes more experienced there becomes a lesser need to follow prescribed procedures. These findings were tested in the Base Maintenance study within the Netherlands. Each of the 82 technicians participating in the survey was asked to judge fifteen statements about working with procedures. The statements presented to the technicians were phrased to include the ADAMS findings in a number of different wordings. In comparison with the outcome of the ADAMS surveys some remarkable results were obtained. About 75% of the technicians agreed with the statement that the need for prescribed procedures varies with the type of task. However, approximately the same percentage (80%) disagrees with the view that the Maintenance Manual is not needed for routine tasks. As was expected an even higher figure of 90% indicated always using the Maintenance Manual when carrying out a test. In the interviews with line maintenance technicians it was clear that procedures were regarded as something that makes the job less satisfying and more difficult. In addition it was stated frequently that work can not be finished in the time available if procedures are followed to the letter. In the Dutch Base Maintenance survey about 75% of the respondents confirmed the statement about the fact that following procedures causes work not to be finished in time. However, 80% of the base maintenance technicians reported to find it satisfying to work with procedures and 66% stated that procedures make the job easier. One statement heard more than once in the Line Maintenance interviews said that there is less need to work according to procedures when a (second) licensed technician checks the work carried out afterwards. In the Dutch Base Maintenance study this attitude was not observed: only 6% of the respondents agreed with this statement. Line Maintenance personnel from the same Dutch company as the one participating in the Base

Maintenance survey had also participated in the Line Maintenance bottleneck survey. No other reason than the type of maintenance (i.e. base or line) unit in which staff was working could be indicated for the differences in attitude towards procedures.

In each of the surveys carried out technicians agreed about the fact that it is difficult to extract information from the Maintenance Manual. A variety of reasons were mentioned. Almost every technician (87% in the Dutch Base Maintenance survey) has come across errors in the Maintenance Manual. Too much detail is another complaint heard quite consistently, both in line as well as in base maintenance. An ergonomic survey of maintenance documentation carried out by Trinity College Dublin also indicated ergonomic problems with the equipment needed to consult the manuals on microfilm. These ranged from poor lighting conditions and not being available of (enough) microfilm readers to (very) poor printing quality. In the surveys conducted within the Netherlands these types of problems were not mentioned.

Of the respondents in the ADAMS survey who said that they had not followed the procedure as laid down in the Maintenance Manual 45% stated that this was because there was an easier or quicker way. No information was gathered as to what specifically made the Maintenance Manual method unnecessarily complex or lengthy. The Base Maintenance survey within the Netherlands aimed to find more detailed information on this aspect. During the data analysis it had to be concluded however that there were too few questionnaires completed in each of the different conditions to allow useful conclusions. As an example: more than 80% of the respondents who had consulted the manual considered the quality of the information to be good (72%) or excellent (10%). Those who responded with an answer less than good reported to criticise the structure of the manual or found it to be outdated. The number of persons answering this question (5) was however too small to draw conclusions. Another question in the survey asked about the quantity of information. Sixty (60) percent of the respondents considered the amount of information to be just good for the task. Of those not satisfied with the amount of information about equal numbers wanted less and more information.

The opinion on the difficulty of information extraction does not seem to differentiate between different manufacturers. However, in the interviews the manuals supplied with American aircraft were frequently criticised for their large amount of warnings and cautions. The number of these is so large that they are said to obscure the real information in the documentation. One technician explained that he often starts reading the procedure after printing it off and after first scratching out all warnings and cautions with a marker pen. Though anecdotally, this is a disturbing indication that the documentation carefully prepared by the manufacturer is not used in the way it is intended, or that it does not meet the user requirements from the technician. A large number of the warnings in these manuals are said to be trivial to an experienced technician. During the interviews more than one technician stated not to read warnings and cautions because they are only included in the documentation for legal (liability) reasons. The danger in these remarks will be clear: there is a conceivable risk that technicians will also skip those cautions that are definitely non-trivial and need to be understood before task execution starts.

Blackbooks

Based on the ADAMS surveys and some task observations conducted by Trinity College Dublin it could be concluded that (especially in line maintenance conditions) maintenance documentation is primarily consulted to check on detailed information like torque or limit values. A specific line maintenance problem is that maintenance documentation is not available at the location where the task is carried out. Certainly on large airports it takes technicians a large amount of time to go and consult the maintenance documentation in a hangar or office building. It is not uncommon that this requires half an hour, which is, for aircraft like the Boeing 737 and Airbus A-320, very close to the total time planned for the turn-around at the gate. Because the perception of the licensed technician is that he does not need the procedure for a large part of the line maintenance tasks there will be a tendency not to fetch the manual but rather to carry out the task using experience from the past. This may pose a problem for detailed information like torque values, part numbers and limits. As a solution a lot of technicians carry a *blackbook*: a personal and illegal notebook in which the technician records useful information for their own reference.

It is not possible to give an estimate of the percentage of technicians using a blackbook, but based on the interviews it is our belief that they probably exist within every organisation. Technicians are very much aware of the fact that these books are illegal and were found to be reluctant to show theirs during the interviews. This sensitivity can be explained by the fact that management in these companies had specifically instructed

technicians to stop using personal notebooks. The use of blackbooks is not limited to Line Maintenance only. In the Dutch Base Maintenance study a number of technicians indicated to have consulted and worked from own personal notes. The survey included ten cases of repair tasks. In none of these cases the Maintenance Manual was consulted, but in five cases the technician did use private notes. From an ergonomic survey of maintenance documentation carried out by Trinity College Dublin it was concluded that the use of blackbooks was ubiquitous (McDonald et al, 1999).

Blackbook figure - see printed report for details
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Figure 3 Example of information stored in personal <i>blackbooks</i>. Left page: tyre damage limits. Right page: abstract of anti-skid test.

Contents and appearance of the personal notebooks differ from individual to individual. Most of the times it will be in the form of a paper booklet that fits in the (breast) pocket of the overall. Some technicians will just retain copies of the maintenance documentation after they have completed a task, while others may write their own abstract of the information (see anti-skid test in Figure 3). Nowadays, also palmtop computers and organisers (e.g. Psion-series) are used as blackbook which, according to the technicians using these, have made it easier to search for a particular topic and to update information contained in the notebook.

Those blackbooks that we did see also contained a lot of information on items that are rarely changed or not directly related to safety critical tasks. As an example, some books contained information on gate numbering and parking positions at the airport. Another technician showed us some notes indicating the position of the emergency lighting battery packs on the aircraft in their fleet. He had started making these notes when the first time he had to replace one of the battery packs he had to open numerous access panels in the cabin before he located the pack.

The largest problem with the existence of blackbooks will be clear. There is a risk that by consulting own private notes or retained copies of maintenance documentation technicians will use outdated information. The result of this is unpredictable but it is not difficult to imagine what the effect on the safety of the operation can be. Yet, there is a second problem with blackbooks that is often not mentioned. Feedback from the workforce to the Engineering department and from there to the manufacturer is negatively influenced. Especially knowledge on supposedly easier or better ways to carry out a task may not reach Engineering. Supposedly, as the interpretation of the improvements discovered by the technicians may differ from that of the manufacturer and Engineering. Further, during the bottleneck interviews technicians frequently indicated that they expect very little effect of them reporting errors found in procedures to Engineering, though this view also seemed to depend on the company involved.

The danger in using blackbooks is clear and yet we hesitate to promote destruction of all blackbooks by tomorrow. The alternative to using a blackbook may even be worse: human memory! As a passenger I would maybe prefer a technician using a potentially outdated number above guessing this value altogether. Of course, the best option would be to take the time to consult the maintenance documentation and follow the procedure prescribed in there. However, we now know that a line maintenance technician often does not choose to do so if it concerns a routine task for which he only needs to look-up specific values. Before banning blackbooks we should take the message visualised by their existence serious: technicians in line maintenance need another form of task support.

The Job Perception Gap

The preceding discussion on procedural compliance and the existence of blackbooks has drawn an image of a double standard. There is an official way of doing things, which is laid out in the documentation, which has a legal status, but which objectively does not meet user needs. Then, there is the way in which work is actually done, which is supported by unofficial documentation and which frequently diverges from the official way (McDonald et. al., 1999). It is stressed that this leaves intact the high level of commitment to safety observed in each of the organisations visited.

One of the main reasons for this double standard stems from a difference in perception between technicians and their managers as to what the task of the technician constitutes. We believe that there exists a *job perception gap* (Biemans et. al., 1998):

- The technician sees himself as being responsible for the safety of the aircraft, and to use his judgement to do what is necessary to ensure this, even when this means that he does something different or more than in the manual described.
- The manager sees the primary role of the technician to follow procedures as laid down in the official documentation. If this is done the safety will be ensured.

Put in the words used by the technician: “I am signing for the airworthiness of the aircraft”. A number of managers have indicated to disagree with this view: “The technician’s signature is there as a statement that the instructed tasks were carried out in accordance with the official procedures.”

In Line Maintenance the job interpretation by the technicians makes that they carry out small inspections (turn-around and daily) without consultation of checklists. What needs to be done and how this should be done is determined on the basis of own expertise and judgement. This could mean that they ignore certain items listed on these checklists although this is not very likely. In most cases they will do the opposite and check more items than expected. What exactly is done during the turn-around will depend on the technicians own experience with problem areas in the past. An example from one of the observations involves brake temperature differences. Though not included in the checklist the technician checked the temperature of the brakes with each turn-around as he considered this to be a good indicator for brake problems. On average a turn-around inspection will take more time than can be calculated using the turn-around checklist. A side effect of not working according to the checklist may be the risk associated to interruption of a task in an area where a normal turn-around inspection would not require action. From their perceived responsibility for the airworthiness technicians feel uncomfortable releasing aircraft with defects even when dispatching is completely in line with minimum equipment lists. In some cases this will be a reason to start a repair or replace parts during the turn-around in a situation where this could also be left until the night shift. The associated risks of carrying out such a task on the ramp and under time pressure will increase. Technicians actually report an increase in time pressure as a result of shortened turn-around times. More effort should be invested in closing the *job perception gap*: we believe it is one of the causes for the time pressure perceived by the technician. Simply enforcing technicians to follow the turn-around checklist to the letter will not solve the problem. This could even have very negative effects as it could remove certain inspection items of which it was not known that they were routinely carried out.

The job perception gap seems to be mainly related to the Line Maintenance situation, but it does present itself in Base Maintenance as well in a different form. We have observed the job perception gap in the situation where technicians spontaneously carry out tasks that are effectively part of a larger inspection. They would inspect areas or systems scheduled for the next C-check during the preceding A/B-check. This can seriously effect the cost effectiveness of the maintenance schedule while it does not contribute to more safety, provided of course that the maintenance schedule was correct. It is even conceivable that such actions have negative safety effects, as the unscheduled tasks could severely influence the planning (time, staff, tools, parts) for the remainder of the check.

Thus, the time pressure experienced by the technician on the ramp may partly be due to the fact that he is doing more than is expected of him. On the other hand, it is remarkable to see the evolution in turn-around times. In addition to the actual inspection of the technical log and the exterior of the aircraft the technician may simultaneously be responsible for service-related items onboard and for other tasks such as refuelling and pushback. It is not uncommon for a technician to service two aircraft parked next to each other which, altogether, makes numerous task interruptions conceivable. The workload that can result from service-related items should not be underestimated. A broken coffee-maker may not be a no-go item according to the dispatch deviation lists, but it can be made one by the cockpit crew. With the current turn-around times there seems to be very little opportunity to leave the aircraft stand to go and consult a manual to look up a procedure, part number or value. That is, unless we are prepared to accept the resulting delay for the aircraft as soon as a defect is found. Whether the technician will actually delay the aircraft or not: we should ask ourselves whether we really want him to delay the aircraft for every simple problem found. One of the problems of the double standard is that we cannot openly discuss what should be considered a simple task and what not. The official way of doing does not distinguish between tasks: everything is done according to the procedures laid down. As an example of the actual way of working: there seems to be consensus among technicians and their managers

about the fact that a wheel change can be carried out without the need to consult the manual and follow it step by step. And yet aircraft loose wheels because a technician applied too much or too little torque or misunderstood configuration differences. How can we manage a system and reduce for instance the costs of operation if the way of operation is not known or (has to be) ignored?

Solution areas to increase the error-tolerance of the maintenance system

The ADAMS results together with the two complementary studies within the Netherlands have determined NLR's approach to study Maintenance Human Factors. With the help from different sponsors research projects were started to work on solutions for improvement in a couple of different areas. The relation between these projects is always that they **work towards the definition of a maintenance system with increased error-tolerance**, and that is less vulnerable for procedural non-compliance. In theory this could be achieved by:

- Reducing the number of written procedures by providing other means of task support,
- Fitting procedures better to the natural or logical way of working,
- Excluding pitfalls in task sequences that could trigger erroneous continuation of the task,
- Making the information contained in procedures better accessible,
- Making people more aware of risks and possible consequences when deviating from procedures.

The time horizons for the projects to achieve final results that contribute to these objectives differ significantly. Work in the training area has resulted in products that have already been put to use, while the other end of the spectrum is characterised by the work on aircraft system design.

In this section NLR's on-going research activities are described. Some of the projects described are conducted in collaboration with other institutes and the industry (see also Figure 1 and Appendix A).

Human Factors Training

The Joint Aviation Authorities (JAA) have set an important step to ensure that Human Factors get the required attention within the maintenance organisations by asking for continuation training in this field as part of JAR-145, and by asking for basic knowledge on a number of Human Factors topics as part of the JAR-66 licensing requirements.

The decision of the JAA can only be applauded, and the subsequent question is what the form and frequency of recurrence of such training should be. It is not very likely that a simple translation of current Cockpit Resource Management courses into Maintenance Resource Management training will meet the actual training need of the maintenance population (van Bavelgem et.al., 2000).

One of the largest pitfalls foreseen and indeed common practise nowadays is the development of ad hoc Human Factors training which is added to the existing (technical) training programmes. Human Factors training however should consist of more than a one or two day module or course to make the technician realise that Human Factors have always been part of the (technical) job and to pass on knowledge of the subject. What's more, it should not be limited to certifying staff only. Hangar and shop managers, as well as staff from supporting departments like Engineering and Quality should just as well be educated in this field. One could even argue that we should have started to deliver training in Human Factors to the personnel around the technicians before training the certifying staff itself. In this light we should take into consideration the ADAMS statement that somewhere down-the-line from the accountable manager to the hangar floor the "Safety First" message gets less clear. When the environment of the technician continues to act and react in the old manner, any attempt by the technician to bring the new knowledge acquired into practise could be doomed to fail.

Despite the valuable step forward, JAR-66 seems to treat Human Factors simply as a body of knowledge which technicians must know, in the same way in which they should know about aerodynamics or aircraft structure (Cromie, 1999). However, in order to establish a lasting and effective change in working practices and behaviour on the maintenance floor, also development of skills as well as building of values and attitudes are important aspects. This cannot be achieved by a Human Factors training of a couple of days. However, it will

be very difficult to get trainees available for much longer, simply because the time spent in the classroom is not seen as productive.

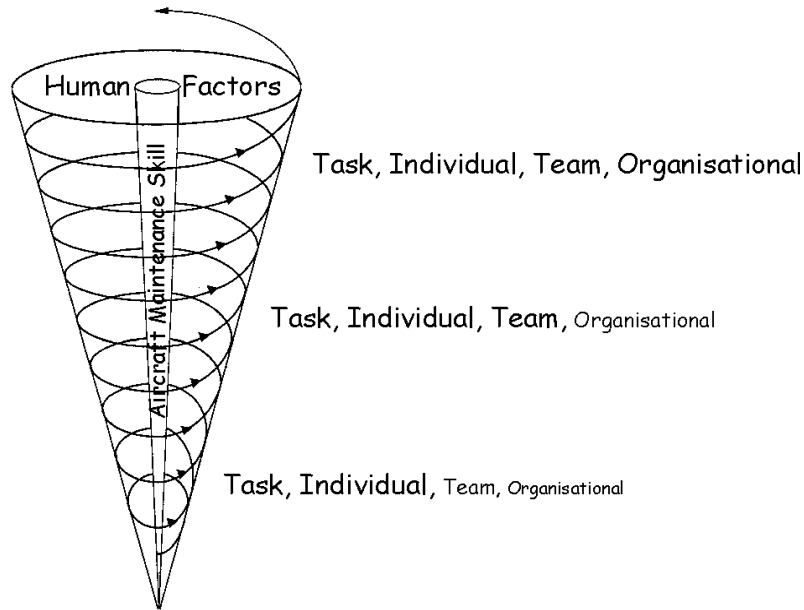


Figure 4 Spiral curriculum; a strategy for integrating Human Factors and aircraft maintenance skills which can be used at macro-, meso- or micro-level (adapted from Palen and Lemay (in Dowding, 1993)).

In addition to the problem that skill development will not be possible with the limited duration of current maintenance Human Factors training NLR sees a second important drawback in the treatment of Human Factors as a separate topic, apparently not directly connected to the technical aspects of the job. It is feared that this will cause Human Factors training to be seen as a compulsory item for Continuation Training without real value in the day-to-day work. Combining the two disadvantages cited NLR's longer term vision is to develop Human Factors training that is integrated with the technical (continuation) training. Full integration of Human Factors in the technical training would mean that for each technical topic, task or system discussed in the Technical Continuation Training the associated Human Factors aspects would be treated at the same time. For the medium term this would still mean that a Basic Human Factors training should be delivered including those Human Factors aspects not specifically linked to a particular task. In the longer term these aspects would be transferred to vocational training. The approach envisaged here is to apply the spiral curriculum model (Figure 4) already applied within other areas of the aviation training domain (van Bavelgem et. al., 2000). In this approach the basic (technical) aircraft maintenance skill is continuously developed while new Human Factors aspects are added one at a time. Already in an early stage the task related aspects would be dealt with. In a next stage the Human Factors aspects related to the individual (e.g. performance effects of fatigue and stress) would be added, followed by the Team and eventually the Organisation related Human Factors. The challenge for training designers is to end with a total continuation training duration that is shorter than that of today (Figure 5).

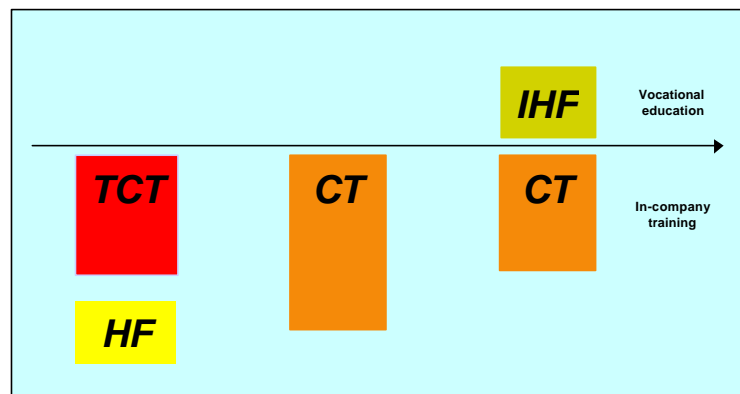


Figure 5 Integration of Human Factors (HF) with Technical Continuation Training (TCT) and introduction of Initial Human Factors (IHF) training in vocational training promises better and more cost-effective results.

The integration of Human Factors in Technical Training cannot be achieved overnight, and the desire to do so does not mean that we should not already train people with the techniques we have available today. With this in mind NLR joined the STAMINA consortium, that was started before the JAR-66 requirements on Human Factors were known. Hence, the STAMINA project cannot be seen as a training that matches the JAR-66 requirements one-on-one. The training was based on what was learned in the ADAMS project, and a first draft of the curriculum was already made in the last phase of this project. When the JAR-66 requirements became known an effort was made by Trinity College Dublin and the Joint Research Centre of the EU to include all the JAR-66 topics in the Individual and Team Modules. The STAMINA training consists of five modules:

1. Introduction module (TCD)
2. Task module (NLR)
3. Individual module (TCD)
4. Team module (JRC)
5. Organisational module (TCD)

The NLR Task Module aims to establish a link between the Human Factors problems encountered in the day-to-day job and specific task situations. The Task Module is an integral part of the STAMINA training, but it can also stand on its own as an introduction of Human Factors. Reflective Discovery Learning forms the main strategy providing the opportunity for trainees to actively participate and reflect on their own job and their experiences in relation to the (to be) handed Human Factors knowledge. The point of departure is to work from realistic scenarios, one of which is presented in the form of a short dramatised film. It was not the intention to focus on theoretical concepts and models, but to hand Human Factor knowledge which would be directly related and applicable to the trainees own job. For this reason discussions on rule- versus knowledge-based behaviour do not appear in the Task Module. Rather, the module focuses on handing the trainees knowledge on the meaning of the five unsafe acts most common in maintenance (Hobbs, 1999), and their relation to specific task elements. To avoid that trainees feel assaulted or feel like they are the primary cause of (and hence the ones to blame for) incidents and accidents, the module intentionally is not based on accidents.

After having received the Task Module trainees should be able to recognise which Human Factors problems particularly play a role given a specific task. The goal is to let technicians assess the associated risks in their day-to-day work after they have returned to their work environment. The underlying assumption is that once the risks are fully appreciated procedural compliance will automatically improve.

We should not ignore the reality as observed in the bottleneck inventory. Technicians will be confronted with situations in which it is not possible to consult the official task procedures or where they are thinking about a short-cut because of operational reasons. With the knowledge handed in the Task Module there is hopefully an increased chance of technicians changing their mind and rejecting the temptation to deviate from the procedures. Hopefully, when for one reason or another the technicians do decide to continue outside the official prescribed method, they will build in extra defences as a safeguard against the most likely unsafe acts.

Organisational learning

One of the tangible products of the ADAMS project is a paper-based tool for incident data collection and analysis. The basis of this tool is formed by the ADAMS Maintenance Error taxonomy. In its turn, this taxonomy was developed after different methodologies to classify human error were studied and reviewed in the light of applying them on maintenance and dispatch activities. Within the ADAMS project the taxonomy was verified to be compatible with the ADREP-2000 classification.

Trinity College Dublin conducted case studies in the participating maintenance organisations to assess how these organisations learned from incidents that had happened. The interested reader is referred to the Human-Centred Management Guide (McDonald et.al., 1999) for a comprehensive report on the findings and the lessons to draw. Here, we only cite some of the main findings that have formed the basis for one of the ADAMS successors.

An important finding from the case studies was that the (quality) feedback systems of the organisations studied were perfectly capable to deal with technical defects found, but not with the human aspects of performance. None of the organisations was said to have an effective routine system to adapt the organisation of work to human operational requirements. Neither quality reporting nor incident investigation led to consistent change in human aspects of the operations. Extended case studies led to the observation that it normally takes more than one incident to achieve a real change (McDonald et. al., 1999).

With the above in mind the AMPOS project was started as part of the European Union Esprit programme. The consortium (TCD, FLS Aerospace, Airbus Industries and NLR) set off to build a supporting IT-environment that would enhance the learning process of organisations after occurrence of an incident. The goal of the project that will be completed in 2001 is to come up with a methodology and the tools to detect, analyse and improve Human Factors bottlenecks within the maintenance system. The supporting tools are build around a network that links the different technical departments within the maintenance organisation, and through the customer's Engineering Department with the manufacturer.

Using the AMPOS methodology incidents are analysed to find causal factors. After a classification based on the ADAMS error taxonomy the data is stored in a database. The purpose of having this database is twofold:

1. Storing the incident analysis results together with a record of the (implemented) recommendations provides the opportunity to keep track of the resulting changes throughout the company over a longer period. The AMPOS methodology details and supports the process to conduct this monitoring.
2. The history of cases solved earlier on can quickly provide insight in how the problem was solved before, and what the longer-term effects of the implemented changes were.

The so-called Smart Engine of the AMPOS system makes the comparison of new cases with the history in the database easy. This Engine is a software module that produces an Automated Similarity Index for new cases entered into the database. This Index highlights possible similarities in the case with existing previous cases. The person investigating the new case can review the similar cases to see if there are any lessons to be learned from. For instance, a quick scan performed in this way could very easily exclude some of the potential solutions for further study as the outcome of earlier business cases might show the solution not to be cost effective. The Smart Engine further contains a diagnostic module that searches for reasons and consequences of cases in technical operational data. A typical outcome of the diagnostic module would be that the number of non-routine cards related to a given ATA-chapter is higher for aircraft with a certain effectivity code when compared to the average number for the whole fleet of that aircraft type.

Any staff member within the organisation can raise new cases with suggestions for improvement of the operation. This implies that proposed cases are first reviewed before an analysis actually is started. The result of such early filtering can be that the expected benefits of solving a case are considered to be too small to investigate. Classification of the case will still be done to allow storage in the database. The AMPOS Smart Engine is prepared to include in a later stage the functionality that would spot similar small cases that were never solved. By combining these cases the Smart Engine would trigger a *meta*-case and bring that up for review by the human operator of the system. Less serious, but frequent, mishaps would thus be tackled where they are probably left unsolved today.

An incident may be the result of such a specific combination of aircraft type, organisational factors and environmental conditions that it appears for the first time within an organisation. The Similarity Index will then not find similar cases in the database. However, another operator of that aircraft type may have solved a similar case. A logical solution would be to share data between organisations, but some forces work against this:

- The anxiety for abuse of shared information by third parties,
- The commercial value of information on solutions or modifications carried out,
- Anxiety about linking networks of different organisations,
- The costs involved in building a safe network with all the users of an aircraft type.

The AMPOS Smart Engine is set up in such a way that these concerns could be overcome by creating a safe “*Virtual Marketplace*”. The initiative to find similar cases in other organisations lies with the information-seeking partner. This partner submits a profile of the case on which information is sought on the Virtual Marketplace. Subsequently the AMPOS database of each of the vendors on the market is polled. The buyer on the market receives Similarity Indices from the vendors, which allows an assessment of possibly comparable cases. The following contact will depend on the arrangements between the buyer and vendor. In this way the AMPOS system would make it possible for users of the same aircraft to benefit from solutions discovered elsewhere with guarantees for the confidential treatment of data.

Maintenance Documentation

In the second phase of the ADAMS project the consortium investigated potential improvement areas. In this phase NLR concentrated on the definition of an improved concept for maintenance documentation in line maintenance, that was demonstrated using an interactive computer simulation (Mesland et. al., 1999). The work was continued after the ADAMS project as part of NLR’s Basic Research program and led to a physical model of a portable maintenance computer that forms the basic interface for the technician with all the maintenance documentation needed.

The starting point chosen was the bottleneck survey finding that technicians find it cumbersome to use information from the Maintenance Manual. In Line Maintenance three main reasons are behind this finding:

1. The documentation is not available at the location where the task is carried out, while technicians do not have or do not allow themselves the time to fetch the information at another location,
2. Technicians state that it is difficult to extract information from the documentation. The structure of the manual is complex while information is spread across a number of different documents. In most cases good searching capabilities still lack and lay-out and task-irrelevant information may obscure the information needed,
3. Technicians believe that for the routine tasks they come across in line maintenance they don’t need the official Manual except for some detailed information.

It seems that technicians have already found a solution that works: useful facts of knowledge are written down in a personal notebook as they come along. Apart from the risk of using incomplete or outdated information the problem with these blackbooks is that the maintenance organisation as a whole does not benefit from the lessons learned by each individual technician. A second objective for the work on maintenance documentation therefore was to support better communication from the technicians to the Engineering department.

The portable maintenance computer envisaged in the resulting concept has, when not in use, dimensions that allow the device to be stored in the breast pocket of an overall. It is slightly larger than a popular organiser like the Psion-V. The most apparent difference with such an organiser is that the device contains a second liquid crystal display where normally the keyboard is located. When the hinge between the two (color) displays is kept small one large display surface is perceived. The size and resolution of the display allow drawings and diagrams to be presented with sufficient detail for the technician to work from.

The functionality of the demonstrator includes some basic features that can be considered standard for modern applications, such as text search functions, revision visualisation and the possibility to place bookmarks. The innovation comes from offering the technician an alternative to his blackbook. He is allowed to make notes or highlight passages for future reference. Next time he needs that specific information he can directly jump to it. The big difference with the real blackbook is that the notes that are made are always linked to a specific paragraph in the manual. This gives the opportunity to warn the technician for a change in that specific paragraph when the moment is there that he needs the information again. Nowadays it is common practise for technicians to review a revision list once every month and often this is done in the coffee room. It remains to be seen whether the technician actually remembers such a revision when he needs the information weeks after.

Based on the high level of professionalism and sense of responsibility observed among technicians it is not very likely that they will not take notice of the warning when confronted with it, provided that they can read the information at the location of the task.

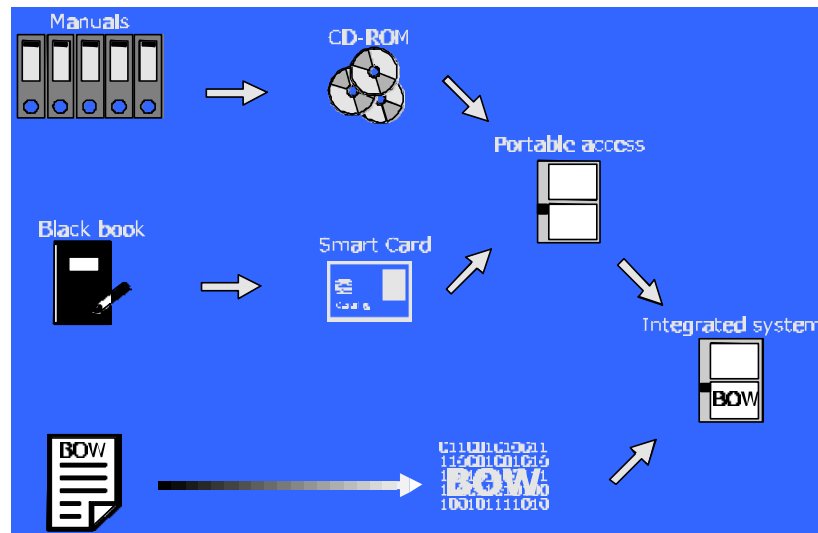


Figure 6 Combining official maintenance documentation with personal notes: building a legal alternative for the blackbook.

In the concept defined the technician's portable computers are part of a network controlled by the Engineering department. The Engineering department has the privilege to review notes that are made by the technicians, although without being able to see which individual made the remark. A typical way of working could be to review a specific paragraph in the manual or a procedure when a given number of technicians have made notes for that part. If the engineer finds that the meaning of the notes reflects a dangerous interpretation or shortcut to the procedure he could take action by sending out a memo to all technicians or by adding his feedback to the specific note. Also, Engineering would be the body to prevent notes or bookmarks being made in specific procedures of which they would require the technician to read the whole procedure each time. By doing so technicians would be helped to distinguish between routine and safety-critical tasks. Again, when the information is available at the task location they will consult it once they recognise it as being critical. At least, we would have made it very easy to use it. Though that is no guarantee that they will actually do so the situation today as described earlier on is clearly worse.

In the longer run the concept could be expanded to include functionality to assign tasks to technicians, register taskcards and to download the technical log or Bill of Work from the aircraft into the technician's computer. The largest problem for adoption of such a concept will probably lie in legal aspects. We understand the difficulty of allowing technicians to treat tasks or procedures differently depending on for instance the level of routine involved. Still we believe that such a discussion is needed, as it is already the current practise observed today.

Design for maintainability (Desmain)

Recently NLR has started the *Desmain* project on design for maintainability under contract by the Netherlands Agency for Aerospace Programs. The rationale for this project is to study how Human Factor problems during the maintenance of aircraft systems could be prevented by the choice of design. Put oversimplified: a technician would probably not apply the wrong torque if only one torque value was used throughout the aircraft. The ultimate result of the Desmain project is to see whether it will be possible in the long term (10 years?) to develop algorithms that can calculate the risk for human error during maintenance given a certain system design. Such algorithms would for instance take into account the possibility for cross-connections. Much nearer in the future the project should define a method to assess a given procedure or task on its error potential by focusing on the cognitive demands put on the technician that uses the procedure or carries out the task. In this way the project is a sequel to the procedures surveys presented earlier on in this paper. Before it is possible to reliably judge a procedure on its error potential we will have to understand what makes that one

procedure is perceived as being more complex than another. In other words, we have to find out what technicians mean when they say that the current procedures do not fit their normal way of working.

One of the first activities in the project focused on seven installation tasks and investigated whether these tasks differ in error potential. Using expert judgement techniques it was first established whether technicians agreed on the error proneness of the different tasks. It was concluded that the technician's judgements about the relative error potential of the tasks are similar (see table I). This suggests that aspects inherent to the task determine the error potential (Hoekstra et. al., 2000).

Table I. Error proneness of seven installation tasks as ranked by eight technicians.

1. Flaps
2. Wing gear
3. Engine
4. Pylon
5. APU
6. Windshield
7. Water ejection pumps

The number of possible errors that were mentioned by the technicians seemed to be related to the relative error potential of the task. In addition to the absolute number of possible errors also the number of different types of errors that are likely during the execution of a task seem to relate to the error potential.

Next to the interviews held with the technicians the documentation of the seven tasks compared was analysed to identify characteristics of the task that may influence the error potential. A number of task factors that require cognitive processes of the technician and that could induce human error were revealed. A number of different factors were already mentioned by the technicians during the interviews, including the number of parts, the number of interpretations, the number of connections, size/heaviness of parts and the number of persons needed to conduct the task. One of the factors not mentioned during the interviews and revealed by the documentation analysis was the number of different parts used in the task.

The Desmain project has just started and the results presented should be considered as a first attempt to understand which cognitive factors play a role. The tasks considered were all base maintenance installation tasks. Guided by the top three of maintenance errors listed by the UK CAA in 1992 (incorrect installations, installation of wrong parts, and wiring discrepancies) the next step will be to analyse specific avionics tasks. This should lead to a list of factors that contribute to cross connections.

When we succeed to find a method that can reliably predict error potential given a certain design it becomes possible to develop algorithms that could help early in the development trajectory to select between different design options.

Conclusions

The ADAMS research project studied nature and extent of Human Factors problems in aircraft maintenance within Europe. A high level of commitment to safety was found in each of the organisations that participated in the study. Nevertheless, ADAMS revealed that in about one-third of all cases technicians deviate from the prescribed Maintenance Manual procedures. Technicians do not see a need to consult the official documentation if it concerns routine tasks. For these tasks the manual is primarily consulted to look up detailed information. Most technicians agree that it is cumbersome to extract information from Maintenance Manuals: structure, the (high) level of detail and errors in the text are criticised frequently. Almost half of the people in base maintenance that did not follow the prescribed procedure from the manual said that there was a better or easier way to carry out the work. It is yet not completely understood what makes that technicians perceive the written procedures in this way. In system and procedure design more effort should be given to particularly understand the cognitive expectations of the maintenance technician.

Probably every maintenance organisation has technicians that use private notes (blackbooks) as a time-efficient (illegal) alternative to the official documentation. Blackbooks clearly indicate the need for another form of task support in line maintenance and for routine tasks. Alternatives that offer similar advantages as the blackbook are technically feasible, though legal matters may pose a problem to start the development of such a form of task support.

Technicians and their managers differ on the interpretation of the technician's job. The resulting Job Perception Gap is one of the causes of the time pressure perceived by the technicians and negatively influences procedural compliance. Within aircraft maintenance a double standard exists: the official and the actual way of working exist next to each other. Technicians and their managers seem to agree that the importance to follow a written procedure is lower for very simple tasks. The impossibility of having an open discussion on this matter makes that every technician for himself determines where the line lies that divides the simple from the critical tasks.

A similar deadlock situation may exist concerning the large number of warnings and cautions in Manuals. These are said to mask the real information in the procedures, and the perception of the (experienced) technicians is that the warnings are not included for them to use the information but merely for legal liability reasons. If we fail to distinguish the critical from the non-critical warnings and cautions we will have to accept the risk of technicians treating the two alike. It is suggested that this could be the topic of a specific research action in which manufacturers, researchers and legal experts should collaborate to find ways to make it obvious for an experienced technician what the safety-critical warning material is.

Procedural non-compliance, blackbooks and the Job Perception Gap manifest themselves both in line as well as in base maintenance. However, the reasons behind them and their appearance may differ between line and base maintenance. Nature and extent of Human Factors problems differ between line and base Maintenance. This asks for a different approach and for different solutions, maybe also when training people in Human Factors.

Maintenance Human Factors training is an important step forward. To create lasting change in attitude and behaviour another form than that of today is needed. Other categories of personnel than just the certifying staff should get some form of education in Human Factors as well. Cost-effective training solutions should be sought by integrating Human Factors in the technical training.

Solutions to the Human Factors problems existing today should not be sought in training alone. Organisational learning, improved system design and better maintenance documentation are areas where the potential for improvement is clear. Each maintenance organisation will have to make its own improvement plan that matches organisational culture and the management systems already in place. However, for the main bottlenecks discussed in this paper it remains to be seen how much the individual organisation can really achieve. A discussion on a higher (international) level may also be needed to determine how to come to improvements industry-wide.

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Appendix A: Description of projects on Maintenance Human Factors

ADAMS Aircraft Maintenance and Dispatch Safety (1996-1999)

Partnership: Airbus Industry (F), British Airways Engineering (96/97), Defence Evaluation Research Agency (DERA) (GB), FLS Aerospace (IRL) Ltd., Joint Research Centre of the EU (JRC) (I), National Aerospace Laboratory NLR (NL), Sabena Airlines, Scandinavian Airline System (SAS), Trinity College Dublin (TCD) (IRL)

Main objectives:

- Inventory of existing Human Factors aspects,
- Development of error taxonomy and incident analysis tool,
- Assessment of influence of new technologies on Human Factors,
- Investigation of role of organisational aspects.

The ADAMS project was sponsored by the European Union under BriteEuramII and was finished March 1999.

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ADAMS II (2001-2004)

Partnership: BAe Systems (operations) ltd. (E), Dédale S.A.(F), Dublin City University (IRL), FLS (IRL), JRC (I), KLM Royal Dutch Airlines (NL), University of La Laguna (E), NLR (NL), Sabena Technics S.A.(B), TCD (IRL)

Main objectives: To analyse the human role in reliability and effectiveness in the systems and processes of aircraft maintenance.- at the level of the task, the person and group, events and incidents, and the organisation. This will support the development and evaluation of tools and methodologies to improve practice in aircraft design, maintenance quality management and organisational learning following incidents and events. The requirements for organisational change to ensure successful implementation of these interventions will be examined and their costs and benefits will be studied.

The ADAMS II project will start March 2001 and will be sponsored by the European Union under the Framework 5 Growth programme.

Contact address: KLM Engineering & Maintenance, Wouter Kunz, HERAM manager, H10 room 0256, 1117 ZL Schiphol-Airport, The Netherlands, Phone: +31-20-6496905 Fax: +31-20-6488802, WN.Kunz@td.klm.nl

ADAPT^{IT} Advanced Design Approach for Personalised Training - Interactive Tools (2000-2003)

Partnership: NLR (NL), University of Bergen (NO), Open University of the Netherlands (NL), Sevenmountains Software AS (NO), Swedish ATS Academy (S), EUROCONTROL (L), Piaggio Aero Industries SpA (I)

Main objectives: ADAPT^{IT} aims to produce a web-based tool for training designers. The tool will embody a validated training design methodology for personalised training that is based on cognitive science and which optimises the integrated use of ICT Training technologies. The tool will provide specific guidance to the training design process, including activities of needs analysis and training evaluation, according to available standards. The quantum leap for improving training lies in the way training technology is used - the “*how*”, not so much in the training technology itself – the “*what*”.

The adaptive-training design aspects of ADAPT^{IT} build on cognitive load theory and are enabled by emerging technologies. Both trainee model and trainee behaviour will be used to feed the ‘instructional’ model within the learning environment for a ‘pragmatic intelligent’ selection of task levels, situations, and the information needed. Although a number of design methods for ‘intelligent tutoring’ are known, ADAPT^{IT} is new in that it addresses the whole range of training design activities, while including aspects of ‘intelligent tutoring’ that relate to cognitive load theory.

ADAPT^{IT} Project is part of the 5th framework IST programme of the EC and supported by DG13. It runs from February 2000 till January 2003.

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AITRAM Advanced Integrated TRaining for Aeronautics Maintenance (2000-2002)

Partnership: FLS, Fraunhofer Institute, JRC, SR Technics, TCD.

Main objectives: To integrate human factors and technical training in a virtual reality training environment. Logistical problems and quality concerns restrict access to aircraft for practical training, and limit the training of many tasks to demonstration or merely description. By modelling tasks in a virtual world, trainees can practice the tasks. By introducing human factors elements into the scenarios, trainees can also learn how to deal with a range of factors that can affect performance.

The AITRAM project will run from April 2000 – September 2002, and was sponsored by the European Union under the Fifth Framework IST programme.

Contact address: Fraunhofer Institut Fabrikbetrieb und –automatisierung, Dept. IVS, Stefan Stuering, Sandtorstrasse 22, 39106 Magdeburg Germany, Phone: +49-391-4090131 Fax: +49-391-4090445, stuering@iff.fhg.de

AMPOS Aircraft Maintenance Procedure Optimisation System (1999-2001)

Partnership: Airbus Industrie, FLS, NLR, TCD

Main objectives: To develop a system to establish initiation and feedback of Human Factors information within the maintenance organisation and between maintenance organisations and the manufacturer. The main purpose of this system that will function in the entire organisation and comprises of both a methodology and an IT system is to initiate a process of continuous improvement to maintenance operations, procedures and processes in relation to the goals of enhanced safety, quality, efficiency and costs. Within the AMPOS project a prototype of this system will be built and demonstrated.

The AMPOS project will run from January 1999 – August 2001 and is sponsored by the European Commission under the ESPRIT research initiative.

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DESMAIN (1999- ...)

NLR's Human Factors department, under authority of NIVR (The Netherlands Agency for Aerospace Programs) conducts DESMAIN.

Main objectives: To reduce human error in aircraft maintenance by considering cognitive human restraints in the design process of aircraft (components). Within the project an Error Potential prediction model is being developed for the evaluation of maintenance tasks to be used during the design phase. The project runs from June 1999. Continuation is decided upon on a yearly basis.

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Human Factors aspects in aircraft maintenance studies for the Dutch Civil Aviation Authority (1997-2000)

These projects were conducted by NLR under authority of the Dutch CAA.

Main objectives: To make an inventory of Human Factors aspects that play a part in Dutch aviation maintenance. The study comprised of three parts: part 1) identification of Human Factors aspects in line maintenance in the Netherlands, part 2) an inventory of Human Factors aspects in relation to procedural non-compliance in base maintenance in the Netherlands and 3) a comparison of the line and base maintenance study and the Dutch and European results

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Integration of Human Factors training into Aircraft Maintenance Training (2000- ...)

Carried out as part of NLR's Basic Research Programme.

Main objectives: The project aims to present a path to the future in which training in Human Factors gradually shifts from Continuation Training to vocational training by integrating Human Factors training into the technically oriented aircraft maintenance training. By such an integration extra time for training can be limited (efficiency) and transfer to the floor can be extended (effectiveness).

In 2001 the project has entered the second phase in which attention is specifically focused on vocational training. In this phase the main objective is to develop and test opportunities and strategies to integrate Human Factors into vocational aircraft maintenance training to come to an initial set of guidelines to incorporate Human Factors in training design.

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Maintenance Documentation, COMMAND (NLR)

Basic research project, conducted by NLR

Main objectives: To provide solutions to reduce procedural non-compliance through improvements and new methods of task support. One approach followed is the study of personalisation of maintenance documentation as visualised by the Blackbook Alternative.

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STAMINA: Safety Training for the Aircraft Maintenance Industry (1998-2000)

Partnership: FLS Aerospace ltd. (IRL), NLR, SAS, TCD; JRC also contributed

Main objectives: STAMINA developed dedicated human factors training for the aviation maintenance industry. The training comprises a core human factors course with additional modules for trainers, managers and supervisors.

The STAMINA project was finished April 2000, and was sponsored by the European Union under the Leonardo Da Vinci programme.

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STAMP Specialised Training for Aviation Maintenance Professionals (2001-2003)

Partnership: FLS, NLR, SAS, TCD

Main objectives: STAMP aims to advance the quality and transparency of training for human factors practitioners in the aviation maintenance industry. Particular target groups are trainers and managers. The project aims to create a framework for certification and accreditation that will become a quality standard in the industry.

STAMP runs until November 2003 and is sponsored by the European Commission under the Leonardo Da Vinci programme

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